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THE CONSTITUENTS OF HEVEA LATEX PART VII.

Studies of the Dependence of the Composition of Latex on various Factors operative in the Plantations*

BY
K. C. ROBERTS

Introduction

Variations in the properties of raw rubber are well known to persist even after the adoption by estates of standardised factory practice, and it has frequently been emphasized in recent times that such variations must be due to other factors operative on estates such as seasonal rhythm, genetic strain and age of the tree, climate, tapping system, soil type and topography. Several aspects of this problem have already been studied, and a comprehensive bibliography of the subject is given by Wiltshire in his monograph.[1]

It is virtually certain that variation in the properties of raw rubber is dependent on variations in its chemical composition and hence in the composition of the latex from which it was prepared. The present communication summarises an attempt, based on systematic analysis[2] of latices collected under carefully controlled conditions, to make a general survey of the effect on the composition of latex of each of the above-enumerated factors. Indications are given of the possible bearing of these effects on the properties of rubber.

Emphasis has been laid in the above on the relationship of these studies to the technically important problem of the *variability of raw rubber*, but their bearing on the question of *latex metabolism* will also be evident.

The phenomena to be considered fall naturally into two groups —those associated with the seasonal rhythm of the Hevea tree (wintering, refoliation, seed development), which is in turn dependent on the normal division of the year into relatively wet and relatively dry periods, and those which, independent of the seasonal rhythm of the tree, may be ascribed to changes in the weather from day to day or from month to month. The two groups cannot be dealt with separately, and the effects of each have been deduced from a consideration of one and the same series of observations.

* The final draft of this paper was completed and submitted for publication shortly before the outbreak of war in Malaya. In March 1950 the manuscript was re-discovered among papers which survived the Japanese Occupation. With the author's consent the paper is now published with minor alterations.—(Ed.).

The latex for investigation was drawn from a small group of mature seedling trees, brought into tapping in April 1937 after a prolonged period of rest and tapped on alternate days throughout the course of the experiment (April 1937 to November 1938 inclusive). The influence of the factors genetic strain and age of the tree, soil type and tapping system has therefore remained constant throughout the course of the observations, and the recorded variations in compositions of the latex, after the initial "settling down" period, are due only to the two climatic factors above mentioned. Quantitative determinations of the major non-caoutchouc constituents of the latex, viz. Fatty Acid Complex, Phosphate Complex and Caoutchol have been made as frequently as circumstances permitted (8-10 times per month) and the observations are recorded in Graphs 1, 2 and 3 as the monthly averages of these determinations. Rainfall was recorded at a point not more than 200 yards from the trees under observation.

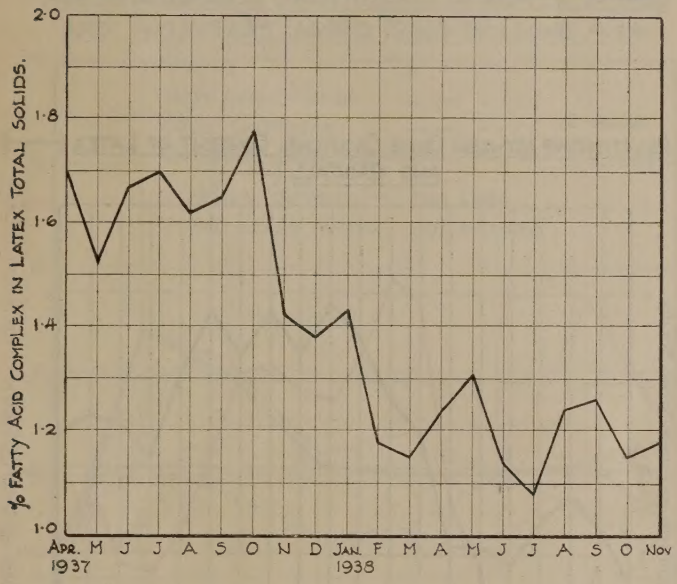
Observations began with the resumption of tapping after more than four years' rest. This fact undoubtedly influenced the findings during the first few months of the experiment, and from the present point of view attention is accordingly concentrated on the results for the latter portion of the period under review.

Fatty Acid Complex.—The monthly average values, initially high, show a falling tendency for some months afterwards (Graph 1). No such tendency has been observed in any other series of determinations of Fatty Acid Complex, and is here attributed to the "settling down" of the mature trees after the re-commencement of tapping. The latter part of the curve is of the same general type as that recorded earlier[3], but shows two maxima (April-May and August-September) following closely on the periods respectively of refoliation (March) and seed-formation (July). It is again observed that no correlation is apparent between the amount of Fatty Acid Complex and the rainfall. The range in monthly average amount of Fatty Acid Complex over the entire period of 20 months (1.1 to 1.8%) is similar to that observed in other series of observations, and is unlikely to exert an appreciable effect on the properties of raw rubber.

Phosphate Complex.—The chief feature of Graph 2, which represents the monthly average amounts of

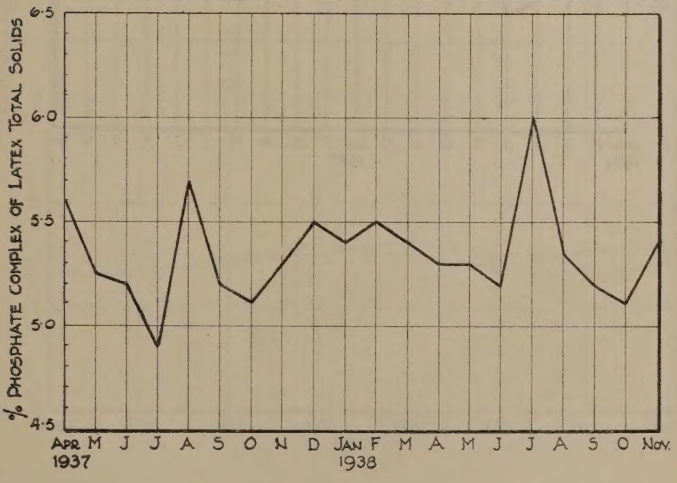
GRAPH 1.

VARIATION IN AMOUNT OF FATTY ACID COMPLEX IN LATEX.



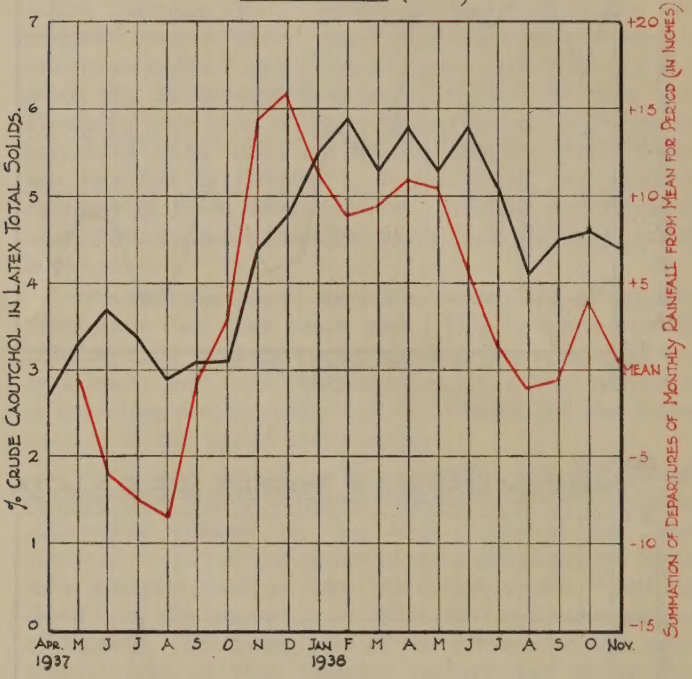
GRAPH 2.

VARIATION IN AMOUNT OF PHOSPHATE COMPLEX IN LATEX.

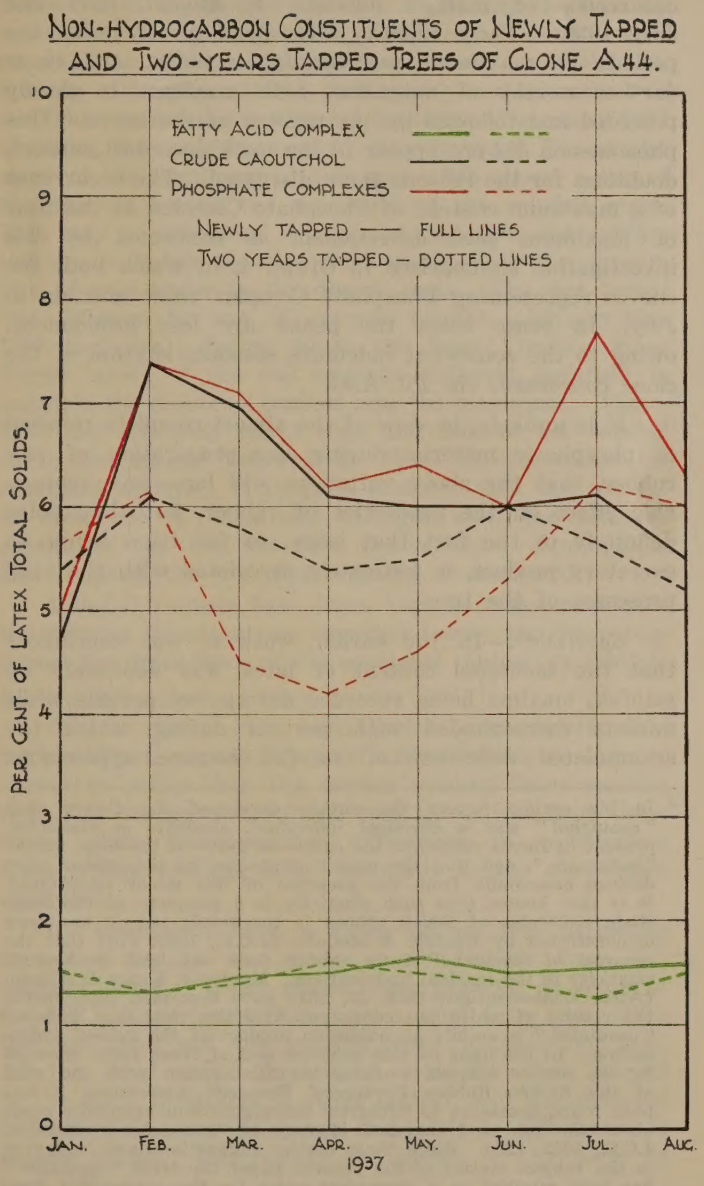


GRAPH 3.

RELATIONSHIP BETWEEN CRUDE CAOUTCHOL CONTENT OF LATEX (——) AND RAINFALL (——)



Graph 4.


NON-HYDROCARBON CONSTITUENTS OF NEWLY TAPPED AND TWO-YEARS TAPPED TREES OF CLONE A 44.
FATTY ACID COMPLEX
CRUDE CAOUTCHOL
PHOSPHATE COMPLEXES
NEWLY TAPPED —— FULL LINES
TWO YEARS TAPPED – – DOTTED LINES
PER CENT OF LATEX TOTAL SOLIDS.
0
1
2
3
4
5
6
7
8
9
10
JAN.
FEB.
MAR.
APR.
MAY.
JUN.
JUL.
AUG.
1937

Phosphate Complex in the latex under review, is the occurrence of marked maxima in August 1937 and July 1938[1]. These months correspond closely with the periods of maximum seed-forming activity, and it is further worthy of note that both maxima are closely preceded and followed by the minima of the curve. This phenomenon did not appear in the work described earlier[3], doubtless for the reasons there discussed. The occurrence of a maximum content of Phosphate Complex at the time of maximum seed development is confirmed by the investigation summarised in Graph 4, in which both the curves representing Phosphate Complex show maxima in July. In these cases the peaks are less pronounced, owing to the somewhat indefinite seasonal rhythm of the clone concerned, viz. Pil. A.44.

It is unlikely, in view of the almost complete removal of phosphatic material during the preparation of raw rubber, that the above variations will have any appreciable effect on the properties of rubber, but they point definitely to the fact that latex, so far from being an excretory product, is intimately associated with the vital processes of the tree.

*Caoutchol**.—In the earlier work it was concluded[3] that the caoutchol content of latex was dependent on rainfall, maxima being recorded during wet periods while minima corresponded with periods during which the accumulated deficiency of rainfall became appreciable.

* In his earlier papers the author developed the theory that "caoutchol" was a chemical individual, alcoholic in character, present in Hevea rubber to the extent of 2-5% of the total rubber "substance", and that the elastic properties of the rubber were derived essentially from the presence of this minor constituent. It is now known that such elasticity is a property of the long-chain molecules of which rubber is composed; and it has been demonstrated by Haefele & McColm (J.C.S., 1939, 676) that the removal of 'caoutchol' from rubber does not lead to loss of elasticity in the residual hydrocarbon. Moreover, Kraay & Altman (Arch. Rubbercultuur, 1938, 22, 231) have described experiments the results of which are consistent with the view that Roberts' "caoutchol" is mainly an oxidation product of the rubber hydrocarbon. In the light of this evidence and of fresh facts revealed by the author himself working in collaboration with the staff of the British Rubber Producers' Research Association it has been found necessary to withdraw the suggestions originally made about the role and chemical identity of "caoutchol" (Roberts, J.C.S., 1942, 223). Since these earlier suggestions are irrelevant to the subject matter of the present paper the term "caoutchol" has been retained as a convenient name for the oxygenated, low-molecular weight material isolated from natural rubber under Roberts' conditions i.e. without deliberate exclusion of oxidative changes.—(Ed).

The present investigation emphatically confirms this conclusion, as is shown by Graph 3. Neglecting the first 4-5 months of the period, during which the results were expected to show anomalies consequent upon the reopening of tapping after a prolonged period of rest, it is seen that during the wet period September-December 1937 inclusive, the caoutchol content steadily rose. The attainment of the maximum in February 1938 shows a lag of two months behind the maximum of the rainfall curve. This may be accounted for by the fact that the surface soil was underlain by clay which would delay the percolation of rain water to the deeper roots. The wet period was followed by one of average rainfall (January-May 1938 inclusive), during which the heavy, badly-drained deeper layers of the soil retained sufficient moisture to maintain the caoutchol content near the maximum. Thereafter the relatively slight rises and falls of the rainfall curve are closely followed by those of the curve for caoutchol content. It is quite probable that the amount of caoutchol in latex also changes with the seasonal rhythm of the tree, but since the variation of rainfall is also seasonal, the two effects cannot be separated.

Rainfall records have been kept in connection with the further investigations reported below, and have confirmed the dependence of the caoutchol content on rainfall.

Genetic Strain of the Tree.

Certain clones, even when grown under widely varying conditions, consistently yield rubbers which are notably harder or softer than the normal product from seedling trees. It has now been found that the latices from these clones show corresponding differences in composition from typical seedling latex, especially in the constituent caoutchol.

To investigate this, a series of analyses extending over two months was made on the latices from five selected clones. These clones were growing in plots at the R.R.I. Experiment Station on a small area over which the soil type and the rainfall were virtually uniform. All the trees under observation were therefore subject to the same variations in other factors, and the observed differences in composition are due solely to differences in genetic strain. The results are shown in the table on page 285.

The clones were selected since they yield rubbers of widely differing physical characteristics. Results for

the latex of a single typical mature seedling tree observed over a similar period, but necessarily growing on a different soil, are included for comparison.

Genetic type of trees	Mean Percentage on Latex of:	
	Fatty Acid Complex	Caoutchol
Clone Tj. 1 ..	1.35	4.2
Clone Pil. A. 44 ..	1.60	5.9
Clone P.B. 23 ..	1.45	6.5
Mature Seedling ..	1.35	6.7
Clone Av. 152 ..	2.50	6.7
Clone P.B. 186 ..	1.70	8.6

The high mean percentage of Fatty Acid Complex in the latex of Clone Av. 152 is notable, but does not appear to be associated with special characteristics in the corresponding rubber. The most striking fact revealed by the table is that the highest mean figure for Caoutchol content (Clone P.B.186, 8.6%) is more than double the lowest (Clone Tj.1, 4.2%). Time has not permitted the extension of the observations over a longer period or the inclusion of other genetic types, but the results are nevertheless highly significant. Also, quantitative determinations of the Phosphate Complex were not possible, but from the point of view of the properties of rubber these would be of only minor interest.

Age of the Tree.

This experiment was designed to enable a comparison to be made between the composition of latex drawn from young trees just brought into tapping and that of similar trees which had been tapping for two years. The trees were all of the same clone (Pil. A.44), were growing in close proximity on identical soils, and were tapped under the same system (A.D.) on the same days. Clone Pil. A.44 was selected on the advice of the Botanical Division of the Institute as being one which gives a good flow of latex from the beginning of tapping and which has a low tendency to premature coagulation in the early stages. Also, it is of special interest as being widely used as a parent in the development of the best R.R.I. clones.

Quantitative determinations of Fatty Acid Complex, Phosphate Complex and Caoutchol have been made on pairs of samples drawn at frequent intervals on the same days over a period of eight months. The findings are plotted as monthly averages in Graph 4, a study of which reveals the following points:

(a) After the first two months during which the group of newly-tapped trees show the expected considerable anomalies, the curves representing *Caoutchol Content* show a rough parallelism, as do also those for the content of *Phosphate Complex*. The initial low value of the the Caoutchol Content of the newly-tapped trees is worthy of note, and may be compared with the similar low value recorded in Graph 3 (April 1937), which represents the Caoutchol Content of newly-tapped mature trees.

(b) The average value of the *Caoutchol Content* of the younger trees throughout the eight-month period is distinctly higher (6.2%) than that of the older trees (5.6%). There is however, as might be expected, a distinct tendency for the monthly average values for caoutchol to approach each other during the course of the experiment. The differences between successive pairs of figures from February onwards are: 1.3, 1.15, 0.7, 0.5, (0.0), 0.45, 0.3. The only value which breaks the sequence of diminishing differences is the one enclosed in brackets. Later investigations (unpublished) have been that the degree of softness of rubber is largely dependent on its caoutchol content; the relatively high caoutchol content of newly-tapped Hevea is therefore of some technical interest.

(c) The average value of the *content of Phosphate Complex* of the younger trees throughout the period is distinctly higher (6.5%) than that for the older trees (5.2%). In this case also the results for the two groups of trees show the expected approach towards each other as the experiment proceeded, although the tendency is somewhat masked by the sharp maximum shown by the younger trees at the time of maximum seed development (July). The sequence of diminishing differences between succeeding pairs of figures from March onwards, viz. 2,6, 2.0, 1.8, 0.5, (1.5), 0.3 shows only one break—the figure in brackets.

Since the bulk of the water-soluble Phosphate Complex is removed during the preparation of plantation rubber, it is unlikely that these findings have any technical importance; but it is virtually certain that they reveal a difference in the metabolism of latex production between very young and older trees. In this connection three further points may be noted. The first latex drawn from the younger trees had a strong odour and a marked yellow colour compared with that from the older trees, while its nitrogen content (0.48% measured on the Precipitated Rubber) was appreciably lower than that (0.78% on the Precipitated Rubber) of the same day's latex from the older trees. Also, the dried film prepared from the first runnings of latex from the younger trees was relatively difficult to dissolve in the standard medium of carbon tetrachloride—acetone.

(d) The pairs of points representing the monthly average values of the *content of Fatty Acid Complex* of the younger and older trees do not reveal any significant differences during the eight-month period.

A final point of difference between the two sets of trees revealed by this experiment, and one not represented in Graph 4, concerns the Dry Rubber Content of the latices. Whereas monthly average values for the D.R.C. of the latex from the older trees varied irregularly during the eight months between 37% and 42%, that of the younger trees showed an almost uninterrupted fall from 40% to 31% during the experiment.

Tapping System.

Tapping procedure frequently varies from estate to estate; indeed, it may be necessary or advisable from time to time to vary the tapping system on a given estate. It appeared possible that this factor might account, at least in part, for the well-known variations in physical properties of plantation rubber. Series of analyses of latices drawn under each of two pairs of contrasted tapping systems have accordingly been made to establish whether such latices show the differences in composition which are presumed to underlie variability in the physical properties of rubber.

The latex samples for a given pair of contrasted tapping systems have been drawn concurrently from mature seedling trees growing on a uniform soil. The effects of the factors seasonal rhythm, age and genetic

strain of the tree, climate, soil and topography have thus been eliminated, and the differences observed, if any, may be ascribed only to the influence of the tapping systems concerned.

Only insignificant differences have been observed between the members of a given contrasted pair with respect to the content of Fatty Acid Complex, Phosphate Complex and Caoutchol. It is therefore concluded that even the more drastic tapping systems commonly used are without appreciable effect on the composition of latex and therefore of rubber.

The findings are summarised below:

Latex Constituent	Mean Percentage in Latex under System:—			
	C/2, d/2,— Periodic, 67%	2C/2, d/3,— 3m/6, 67%	C/2, d/2,— 100%	C/2, d/1,— m/2, 100%
Fatty Acid Complex	1.45	1.35	1.7	1.6
Phosphate Complex	4.3	4.1	—	—
Caoutchol ..	4.8	5.2	5.8	5.6

In this table the figures in the first and second columns are comparable and those in the third and fourth columns are comparable, but the two pairs of columns are not comparable because they refer to trees growing under different conditions. The figures in all cases represent the mean of numerous analyses made over a period of months.

Soil Type and Topography.

No intensive study of the effects of these two factors on latex composition was made, but in the course of the investigations recorded above, latex samples have been drawn from a considerable range of soil types and from localities differing widely in topographical feature. Study of the accumulated data has revealed a number of points throwing light on the nature of the influence of these two factors. For example, Hevea growing on light, well-drained soil has been repeatedly observed to react rapidly to rainfall conditions. Thus the caoutchol content of latex produced on the area of sandy soil at the R.R.I. Experiment Station has shown wide variation attributable to this cause, even between successive samples drawn from the same group of trees. On the other hand, in two further experiments (Ampang Road smallholding and

Seventh Mile Estate) involving badly-drained soil, the day-to-day variations of caoutchol content were consistently smaller, while in the former case, in which the surface soil was underlain by clay, slow percolation of rain-water to the deeper roots led further to a lag of the rise of the caoutchol curve relative to the rise of the rainfall curve (Graph 3).

The effect of contrasted topographies is seen on comparing the two studies of seasonal variation in the composition of latex. The one already reported[3], which involved trees standing on steep, unusually well-drained hillsides, showed very close correlation between rainfall and the caoutchol content of the latex. In the present study (cf. Graph 3), the level, low-lying and badly-drained terrain of the Ampang Road smallholding retained sufficient moisture after a period of heavy rainfall to maintain the caoutchol content at a high level throughout a succeeding period of only average rainfall.

In the above, the soil and topographical factors are considered only in conjunction with the climatic factor. A strongly-marked soil characteristic or topographical feature might in itself be expected to yield a latex of composition permanently and significantly different from the normal. No such case has however yet been encountered. The variations encountered have all been ascribable to the factors discussed above.

Summary and Conclusions.

The estate factors most likely to induce variability in raw rubber are factory practice, seasonal rhythm, genetic strain and age of the tree, climate, soil, topography and tapping system. The first of these has already been fully discussed by others, and recommendations have been made to eliminate variations due to this factor. Of the remainder it is now shown that *seasonal rhythm*, *age of the tree* and *rainfall* all produce appreciable variations in the composition of latex, at least with respect to certain constituents. More important differences in latex composition are associated with differences in the *genetic strain of the trees*. Circumstances have not allowed a close study of the effects of the factors *soil type* and *topography*, but indications obtained from the results of the other investigations show that these too, operating in conjunction with

the climatic factor, have an appreciable effect. The most widely contrasted of the recognised *tapping systems*, on the other hand, are practically without effect.

The factor *genetic strain of the tree* is the only one which appears capable of exploitation to yield consistently a rubber having specified properties.

It is evident that many of the findings now reported have a bearing on the problem of latex metabolism.

Acknowledgments.

I wish to acknowledge my indebtedness to Officers of the Botanical Division of this Institute for helpful discussions in the planning of certain of the experiments, and to Officers of the Soils Division for their ready co-operation whenever it was sought. I also take this opportunity of thanking the Managers of Seventh Mile Estate and of the R.R.I. Experiment Station for numerous facilities afforded, and Mr. K. H. Rajagopal for much of the analytical work and the keeping of records.

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